Are the J/ψ and χ_c A Dependencies the Same?*

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The description of particle production in pA interactions as a simple scaling of the pp production cross section with mass number A,

$$\sigma_{pA} = \sigma_{pN} A^{\alpha} , \qquad (1)$$

has been used to describe many processes. The factorization theorem suggests that α should be unity. Drell-Yan production agrees with $\alpha = 1$ to rather high precision with some deviation at large values of Feynman x, $x_F = p_{||}/p_{\rm max}$. A less than linear A dependence has been observed for J/ψ, ψ', Υ, and $\Upsilon' + \Upsilon''$ production with $0.9 < \alpha < 1$ near $x_F \approx 0$.

The A dependence of J/ψ production at $x_F > 0$ is known at several different energies. The ψ' A dependence is not as well known but it was recently found that its α is smaller than the J/ψ α for $x_F < 0.2$. The J/ψ A dependence has been used to determine the strength of the "anomalous" J/ψ suppression. However, an important assumption in this interpretation is that all charmonium states interact while in "pre-resonant" $|(c\overline{c})_8 g\rangle$ states. Since $\sim 40\%$ of the observed J/ψ's come from χ_c decays, a measurement of the χ_c A dependence is crucial for the understanding of J/ψ suppression. No measurement of the χ_c A dependence has yet been made.

Now the χ_c A dependence will be measured in two fixed-target experiments at different energies. The NA60 collaboration has been approved for pA measurements at 450 GeV and nucleus-nucleus interactions at 158 GeV [1]. They will have forward x_F coverage only. The HERA-B collaboration at DESY has placed target wires around the halo of the 920 GeV proton beam at HERA [2]. They will measure the J/ψ, ψ', and χ_c A dependence over $-0.5 < x_F < 0.3$, the first charmonium experiment with coverage significantly below $x_F \sim -0.1$.

If the J/ψ and χ_c A dependencies are the same, then the picture of a pre-resonant color octet state will be validated. Then charmonium production and absorption at fixed-target energies can be essentially described within the color evaporation model. However, the nonrelativistic QCD model predicts that χ_c production should be predominantly color singlet while direct J/ψ and ψ' production is via color octet states. If this picture is correct, the A dependence of χ_c production could be quantitatively different than that of the J/ψ and ψ'.

Here we focus only on charmonium production and nuclear absorption for a clear illustration of its A dependence since it is the only effect that causes the A dependencies of the charmonium states to differ substantially. At larger negative x_F, the A dependence may be different than expected from pre-resonant absorption, depending on the production mechanism, as we demonstrate. Other nuclear effects do not depend on the identity of the final charmonium state, see Ref. [3] for details.

When considering charmonium production in a pure color state, as in the color evaporation model, we find little difference in the charmonium A dependencies in regions accessible to past experiments, in agreement with the J/ψ and ψ' measurements to date. However, when the χ_c is considered, its large color singlet component results in a substantially different A dependence in the nonrelativistic QCD description. This difference should be easily detected by NA60 and HERA-B. Their results should quickly answer the question posed by the title of this paper.

[1] A. Baldit *et al.* (NA60 Collab.), Proposal SPSC/P316, March 2000.
[2] HERA-B Report on Status and Prospects, DESY-PRC 00/04.
[3] R. Vogt, Phys. Rev. **C61** (2000) 035203.

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